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PROGRESS REPORT

AIRPLANE SPRAYING WITH DDT TO CONTROL THE JACK-PINE BUDWORM

1950

By

Charles B. Eaton

Forest Insect Laboratory
Milwaukee, Wisconsin
November 30, 1951

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UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH ADMINISTRATION

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Forest Insect Laboratory
628 E. Michigan Street
Milwaukee 2, Wisconsin
January 29, 1952

To: James C. Evenden, Entomologist in Charge, Forest Insect Laboratory, Coeur d'Alene, Idaho

From: Charles B. Eaton, Entomologist in Charge, Milwaukee Laboratory

CBE

Subject: Progress report: "Airplane spraying with DDT to control the jack-pine budworm - 1950."

We are enclosing a copy of subject report for your information and files, in accordance with your request of January 24th.

Enclosure (1)

Gibson 2-8
Johnson
Terrell 2/11
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Denton 2/11
Evenden

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INTRODUCTION

The jack-pine budworm, Choristoneura sp., is a common defoliator of jack pine, Pinus banksiana Lamb., that has appeared periodically in outbreak numbers in the Lake States. During the 1950 season the jack-pine budworm occurred in epidemic proportions in natural and planted pine stands in various parts of Michigan. The principal area of infestation extended over a wide section of the central part of the lower peninsula. A second and much smaller infestation occurred on the upper peninsula. This second infestation was confined principally to planted stands interspersed with groups of naturally established jack pine on the Rapid River District of the Hiawatha National Forest. Because of the need for information on the value of airplane sprays in controlling the insect, the favorable location of the terrain, and the general suitability of the plantations for the purpose, an experimental control operation was conducted in the Rapid River area during the summer of 1950.

The use of DDT sprays applied by airplane to control the spruce budworm, Choristoneura fumiferana (Clem.), of which the jack-pine budworm, Choristoneura sp., has long been considered a variety, is not a new thing. Tests to control this insect with airplane sprays were conducted in eastern Canada as early as 1944, and have been carried on in various parts of the United States each year since that time (Eaton, et al, 1950). More recently the method has been used on a large scale to control extensive infestations of the spruce budworm in the western part of the country (Lindsten and Wright, 1951). So far as is known in none of this work has there been an occasion to use DDT sprays against any of the forms of the budworm that attack pine. There is little reason for believing that the jack-pine budworm would prove more difficult to control than the spruce budworm. However, in view of the possibility that a need might develop for the spraying of extensive areas to control the insect, it was considered advisable early in 1950 to conduct an experimental operation to confirm the assumption. This was the primary objective of the work reported herein.

The spraying project was a cooperative undertaking in which personnel of the Upper Michigan National Forest, U. S. Forest Service, and the Milwaukee Forest Insect Laboratory participated. The Forest Service furnished the spray materials, which were mixed at the Rapid River Ranger Station. District Ranger James W. Jay was in charge of this work and in addition provided assistance for marking the area, and handling plane loading operations. He also furnished various records and maps needed for the study. The cost of applying the spray was borne by the Bureau of Entomology and Plant Quarantine. Technical direction of the work and the evaluation of the results was the responsibility of the author. H. C. Chapman and D. M. Benjamin assisted in the collection of the field data and in other technical details. Spraying service was furnished by the Aerial Crop Control Company, Escanaba, Michigan.

EXPERIMENTAL AREA

The site selected for the work was a half section block of infested jack pine plantations on the Stonington peninsula, east of the mouth of the Whitefish River (Figure 1). The location of the study area was chosen so that it would include mostly only the older and more heavily infested jack pine plantations on the peninsula. For this reason it included parts of 4 sections, as shown on the accompanying map. The sprayed block is a part of extensive plantings in the vicinity, administered by the Rapid River District. The plantings for the most part are restricted to sand plains, and are readily accessible via a profusion of rut roads that traverse the area. The terrain is comparatively flat, with few obstacles to aerial spraying operations.

The stands on the north half of the test plot are made up of jack pine planted in 1941, while most of those on the south half are older jack pine planted in 1939. A small planting of red pine established in 1947 is included in the area. In addition to the planted trees, individuals and small groups of natural jack pine are present throughout. Many of these trees, particularly the isolated individuals, are of the orchard type commonly found on such sites.

The jack-pine budworm outbreak on the Stonington peninsula extended over an area of about 7,000 acres in 1950 (Eaton, 1950). The outbreak was first reported in 1949, but undoubtedly the budworm has been active in the area for a much longer period. Defoliation in stands classified as being moderately or heavily infested in 1950 was noticeable, but not conspicuously so. Tree mortality has been negligible thus far, except for those trees planted beneath overtopping, orchard type jack pine. The area selected for spraying is near the center of the moderately to heavily infested zone, and is almost completely surrounded by infested trees.

SPRAYING EQUIPMENT

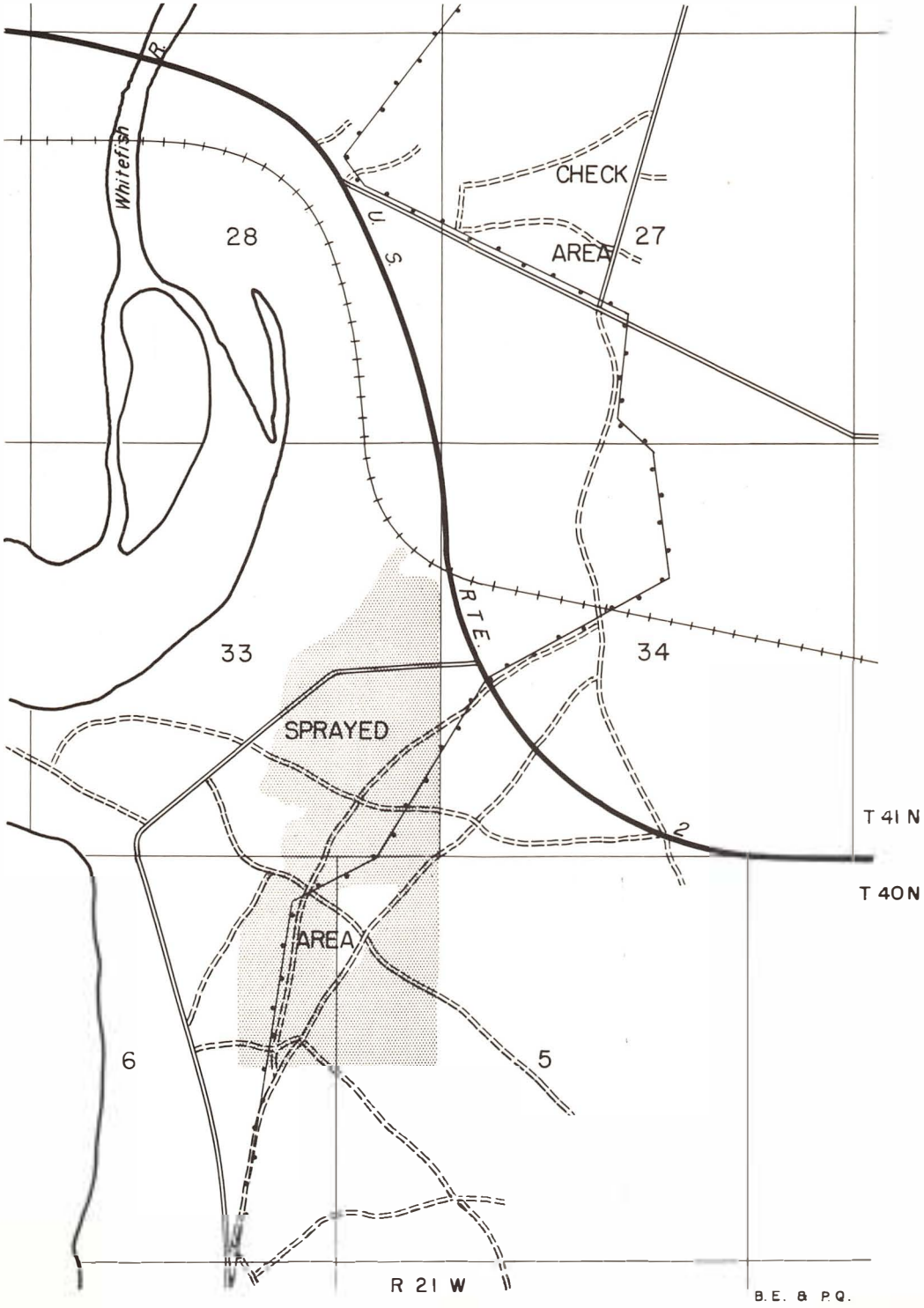
The operator who provided the spraying service used a Piper Cub fitted with spraying equipment manufactured by Ong Aircraft, Kansas City, Missouri. The trade name for the spraying outfit was "Aero Sprayking, Model P-1, 49." This equipment consisted of a 40-gallon cylindrical tank, a gear pump with a bypass line, a pressure regulator and the usual nozzle boom. The boom was fitted with 13 V-jet nozzles ("Spra-jet Jr.") each producing an 80° fan-shaped spray, and having a rated delivery of 0.6 gallons per minute at 40 pounds per square inch.

It was calculated that for a swath width of 1 chain, and at an operating speed of 60 miles per hour, a flow rate of 8 gallons per minute was required to obtain an application rate of 1 gallon per acre. The rated delivery of the thirteen 80.6 nozzles was 7.8 gallons per minute. Circumstances did not permit as thorough calibration of the spraying equipment as might have been desired. However, tests on the ground and in the air, using water rather than fuel oil as the spray liquid, indicated that the rated output of the spray equipment was approximately correct. One feature of the apparatus that was of advantage, especially for calibration work, was a transparent plastic tube on the outside of the spray tank that was connected so that the liquid level within the tank was visible at all times.

Figure 1

JACK-PINE BUDWORM
AIRPLANE SPRAY TEST AREA
1950

RAPID RIVER DISTRICT
HIAWATHA NATIONAL FOREST



In actual operation during spraying, the performance of the spraying equipment and that of the aircraft was quite satisfactory for the size of the experimental tract. The airplane was operated from an airstrip in Rapid River, the limitations of which would have precluded a larger plane. The strip, within a short distance of the Ranger Station, was only three miles from the spraying area, so that a minimum amount of time was consumed in ferrying, in spite of the limited tank capacity which made frequent refills necessary. No difficulty was experienced in maneuvering for spray runs as the forest canopy was practically level, enabling the spray operator to align his flights on the swath marker with very little difficulty.

SPRAYING OPERATIONS

Timing

In tests with aerial sprays to control the spruce budworm, it has been the practice to delay treatment until the majority of the larvae reached at least the fourth instar, and to complete it before the prepupal stage is reached. As this practice has produced satisfactory results, it was considered advisable to follow the same procedure with respect to the timing of spray applications to control the jack-pine budworm.

The progress of budworm development was determined from head capsule measurements of approximately 100 larvae collected at 2-day intervals between June 20 and July 2. The larvae, incidentally, were sexed and the frequency distribution of the head capsule measurements of males and females plotted separately (Figure 2) since it has been shown by Lejeune (1950) that in the later stadia the head capsule widths of the two sexes differ markedly. Although the precaution of sexing the material was taken in this case, in practice it is doubtful if the extra labor involved is justifiable. For spray timing purposes, the disparity in head capsule size for males and females in a given instar is not of practical importance.

According to the data obtained from head capsule studies (Table 1), 95 percent of the larvae were in the fifth and sixth instars on June 26 when spraying began. Of the remainder, 4 percent were in the seventh instar. When spraying was terminated 2 days later (weather conditions having prevented completion of the job during the intervening period) between 71 and 82 percent of the larvae were in the fifth and sixth instars, with between 16 and 27 percent of the remainder in the seventh instar. Had circumstances permitted it would have been advisable to have begun spraying about 2 days earlier in order to complete it during the optimum period from the standpoint of larval development.

Materials and Application

The spray materials, furnished by the U. S. Forest Service, were mixed at the Rapid River Ranger Station. The spray formulation consisted of 1 pound of DDT dissolved in 1.2 quarts of an auxiliary solvent and made up to 1 gallon with fuel oil. The rate of application was one gallon of finished spray per acre. A total of 336 gallons of spray were prepared for use on approximately 320 acres; the extra 16 gallons being an allowance for overrun, spillage, etc. Difficulty was experienced in getting all of the DDT

into solution, and some of the undissolved crystals caused clogging in filling the spray tank. The deficiency in the spray concentration, which resulted from the failure of the DDT to completely dissolve, was of negligible importance as compared with the mechanical difficulties encountered in handling the incompletely mixed materials.

In order to define the limits of the test plot, cloth markers on poles were erected at the principal corners and at half mile intervals on the longer sides. Individual spray runs were marked with a balloon which was elevated for each spray run at 1 chain intervals along an east-west line mid-way between the north and south boundaries of the plot (Figure 1). The spray was released at a height of about 25 feet above the average level of the crown canopy. As previously mentioned, spraying was begun on June 26 and the most westerly one third of the plot was completed on that date. Because of strong winds the balance of the plot was not treated until June 29. The mortality counts did not show any pronounced difference in the degree of control on parts of the plot treated on the two different dates.

EVALUATION OF RESULTS

In order to determine the degree of control obtained, larval counts were made before and after treatment on sprayed and unsprayed areas. Information on the length of time during which larval fall took place was obtained from drop cloths placed under several of the trees. In addition, counts were made of the larval population present in the spring of 1951, one year after spraying, to determine the extent to which reinfestation occurred in the sprayed area.

The counts immediately before and after treatment in 1950 were made on 20 sample trees in the sprayed area and on 10 trees in the check. Sample trees were selected which would provide a fairly representative cross section of the stand. On each tree, larvae on five 15-inch twigs were collected and counted on June 25, one day before spraying operations were begun. On July 10, eleven days after spraying was completed, the same trees were examined and larval counts made on five additional 15-inch twigs. The results of this work are summarized in Table 2.

Table 1. Larval Development of the Jack-pine Budworm in Pine Plantations on the Rapid River District, Hiawatha National Forest, 1950

Date	Total Number Larvae Collected 1/	Percent of Larvae in Each Instar 2/						
		II	III	IV	V	VI	VII
June 13	110	2.7	87.8	8.2	1.8		
" 20	83		4.2	71.0	19.1	5.7	
" 22	79			47.4	48.4	4.2	
" 24	82			6.7	72.4	19.5	1.4
" 26	74			1.3	44.1	50.4	4.2
" 28	87			2.0	21.8	60.3	15.9
" 30	102			2.0 3/	5.8 3/	65.4 3/	26.8 3/
July 2	97			3.7	18.1	51.6	26.6
" 11	73				9.1	4.5	86.4

1/ Exclusive of parasitized larvae.

2/ Values are means of percent males plus percent females in each instar on dates listed; derived from head capsule measurements.

3/ Percentage for males only.

Table 2. Number of Jack-pine Budworm Larvae per Sample Unit on Unsprayed Jack Pine and on Jack Pine Sprayed by Airplane with DDT - Rapid River District - Hiawatha National Forest

Dosage per Acre DDT (lbs.)	Solution (gals.)	No. Trees Sampled	No. Larvae per 15-inch Twig Before Treatment	No. Larvae per 15-inch Twig After Treatment	Reduction Total (percent)	Reduction Spray (percent)
0	0	10	14.26±0.97	8.90±0.58	37.59	-
1	1	20	9.99±0.47	0.03±0.02	99.70	99.52*

* Difference in mean mortality on sprayed as compared with unsprayed trees is highly significant.

$t = 3.26$

1% Level = 2.763

These data show that there was a pronounced reduction in the budworm population on both sprayed and unsprayed areas during the period that elapsed between the pre- and post-treatment counts. However, a much greater reduction occurred on the sprayed area; the difference in mean mortality on sprayed and check units is statistically highly significant. The percent reduction attributable to the spray on the treated area is 99.5 percent. It is apparent that the initial larval populations on the sprayed and check areas were not the same, the check having over 14 larvae per 15-inch twig as compared with 10 for the sprayed block. Since in both cases the population is comparatively high, it is not likely that the difference seriously affected the results.

The cloth trays set up in this study were employed principally to furnish some evidence of the effect of the spray on the larvae, rather than as a means of determining the degree of kill. For this reason only a very small number were used, and these were placed under orchard-type jack pine trees that were known to be heavily infested. A summary of the data obtained from the use of these trays is given in Table 3.

Table 3. Jack-pine Budworm Collections on Cloth Trays Beneath Sprayed and Unsprayed Jack Pine Trees - Rapid River District, Hiawatha National Forest

Tree and Tray No.	Tree D.B.H. (in.)	Tree Height (ft.)	Tree Crown Area* (sq. ft.)	Tray Area (sq. ft.)	Tray Percent of Crown Area	Cumulative Larval Drop 3 Days After Spraying Total	Cumulative Larval Drop 3 Days After Spraying Per Sq.Ft.
Sprayed							
1	7.5	30	133	27.5	20.7	393	14.3
2	6.9	20	95	25.5	26.8	683	26.8
3	6.7	28	113	25.5	22.6	884	34.7
Mean	7.0	26	114	26.2	22.9	653	24.9
Check							
1	4.9	25	133	25	18.9	2	0.1

* Area of circle having diameter equal to crown diameter.

From these data it is calculated that a total of 2,839 larvae dropped from the average tree beneath which trays were placed. If it can be considered that this number represents 99.7 percent of total larval population, as might be inferred from the data in Table 2, then it is calculated that the total number of survivors per tree would be approximately 8. The records of daily collections from the cloth trays within the treated area show that about 80 percent of the total larval fall occurred during the first two days after spraying.

In view of the fact that the half-section plot sprayed in 1950 was located in the midst of an infestation covering several times the equivalent area, it was considered probable that reinfestation would occur once the adults appeared. The adults are known to be capable of covering considerable distance; furthermore, the residual effects of the DDT would largely be dissipated by the time they emerged; thus, reinfestation of the plot was more or less inevitable. In order to obtain information on this point, the plantations involved were reexamined in the spring of 1951. Between June 12 and June 20, twig samples were examined on 185 trees within the sprayed plot, and on 110 trees in the surrounding stands. The results of this survey are shown in the following tabulation:

Treatment	Number of Trees Sampled	Number of Larvae per 15-inch Twig	
		Mean	S. E.
None	110	7.71	± 0.21
Sprayed	185	1.54	± 0.13
	Difference	6.17 *	± 0.47

* Highly significant t = 13.13 1% Level = 2.592

From these data it is evident that the larval population on the sprayed block one year after treatment was approximately one-fifth as great as that in the surrounding area. Since only a very small fraction of the 1950 larval population survived the treatment, it seems probable that adult migration from adjacent stands accounted for the comparatively large number of larvae present in the spring of 1951. However, it is possible that the deleterious effects of the insecticide on natural enemies of the budworm favored an abnormally high survival rate among the progeny of the 1950 population remaining on the sprayed area.

These results have some application in connection with questions that frequently come up regarding the advisability of spraying roadside strips and recreational areas. The spraying of such areas in budworm infested stands has been considered as a maintenance control measure where values of aesthetic importance were at stake. In the light of present experience the practice could only be advocated where it was economically feasible to use sprays nearly every year during the course of the budworm outbreak. The beneficial effects of a single season's treatment in cases of this kind, would be of short duration and probably would be quickly obliterated, unless the spraying was repeated at the proper time each season.

NOTES ON BIOLOGY AND NATURAL CONTROL

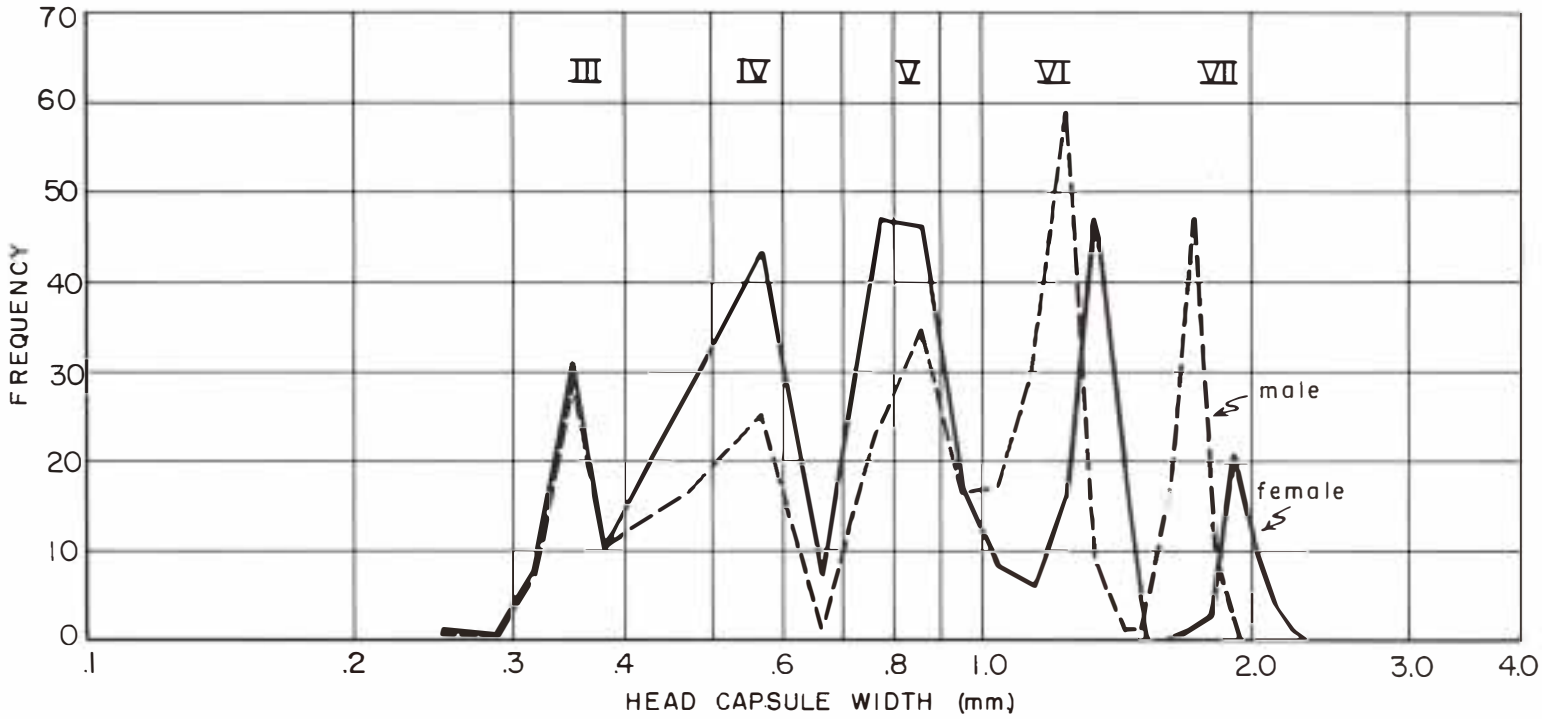
Larval Development

In a preceding section of this report, some consideration was given to the technique employed in determining the status of larval development at the time of spraying. It will be recalled that periodic collections were made, the larvae sexed, and the various stadia represented among the non-parasitized larvae were determined by means of head capsule measurements. The collections were not begun early enough to include the second instar, but the remaining instars were well represented. While none of the material was segregated by food source, the frequency distribution of head capsule widths (Figure 2) is in general agreement with the findings reported by Lejeune (1950), in his studies of larval size in relation to food. The head capsule measurements fell into distinct and fairly well defined frequency distributions for both male and female larvae. The difficulty that Lejeune encountered in obtaining discrete distributions for separating certain stadia of the males was not evident in the present studies. However, it is possible that smaller units of measurement would have disclosed similar variations that are now obscured.

Development of the jack-pine budworm is comparatively rapid, once feeding is well underway, as is illustrated by the data summarized in Table 1. On June 13, when the first collections were made, 87 percent of the population were in the third instar. At this time the new needles had barely begun to grow, and most of the larvae were well concealed. Ten days later nearly three-quarters of the population was in the fifth instar, and 20 days later over 25 percent were prepupae. The basic data from which Table 1 was compiled show that there was a slight difference in the rate of development of male and female larvae. This difference was especially pronounced during the latter part of the larval period, for not only were there fewer instars represented in the male collections then, but also there was a higher percentage of males than females in the later instars. In the July 2 collections, for example, the number of instars represented and the frequency distribution by sexes were as follows:

Figure 2

FREQUENCY DISTRIBUTIONS OF HEAD CAPSULE WIDTHS OF MALE AND FEMALE JACK-PINE BUDWORM LARVAE



Instars	Males (percent)	Females (percent)
IV	0	8
V	5	31
VI	51	52
VII	44	9

Regardless of minor differences in the development rate of the two sexes, the period during which the larval population as a whole is most susceptible to control by sprays is rather short, at most of 10 days to two weeks duration.

Parasitization

As a matter of interest, and to avoid confusion that would result from the presence of parasitized specimens among the material analyzed in the growth studies, all larvae collected were dissected and those that were parasitized were set aside. An exception was made in the collection of June 13 which was composed almost entirely of small larvae. Dissection of the remainder of the material, totaling nearly 800 larvae, showed the average parasitization to be 11.5 percent (Table 4). Parasite species recovered, which were identified by P. B. Dowden of the New Haven, Connecticut Forest Insect Laboratory, were Glypta fumiferanae (Vier.) and Apanteles fumiferanae Vier. L. R. Lejeune of the Dominion Entomological Laboratory, Winnipeg, Ontario, Canada reports the recovery of 11 species of ichneumonid and 12 species of dipterous parasites from jack-pine budworm larvae.

Table 4. Parasitization and Sex Ratio of Jack-pine Budworm Larvae in Pine Plantations on the Rapid River District, Hiawatha National Forest - 1950.

Date	Total No. Specimens Collected	Larvae: Percent Parasitized 1/	Percent Unparasitized: Males	Females
June 13	110	-	-	-
" 20	104	18.3	33.6	48.1
" 22	100	20.0	37.0	43.0
" 24	93	11.8	37.6	50.6
" 26	89	15.7	39.3	45.0
" 28	107	17.8	34.6	47.6
" 30	102	5.9	51.0	43.1
July 2	106	7.5	41.5	51.0
" 11	104 2/	18.9	32.2	48.9
	Mean	14.5	38.4	47.2
	SE	±1.9	±2.1	±1.1

1/ Parasite species Glypta fumiferanae (Vier.) and Apanteles fumiferanae Vier. (identified by P. B. Dowden, Forest Insect Laboratory, New Haven, Conn.).

2/ Includes 14 pupae.

Glypta and Apanteles were included among the 4 species of ichneumons listed as most common. In two of the eight collections in the present study, average parasitization was less than 8 percent; in the remainder, the average was 12 percent or more. Sampling error probably accounts for the variation between the individual observations.

Sex ratio

In commenting on studies of the sex ratio of the jack-pine budworm, Graham (1935) observed that probably the proportion of sexes is equal under normal conditions, but that possibly females normally exceeded males in number. Data collected in the present study (Table 4) would indicate the latter to be true if it can be considered that "normal conditions" prevailed in 1950. In all but one of the collections in which the larvae were sexed, the females consistently exceeded the males

in number, the ratio of the means being 1.23 to 1. The average sex ratio, 0.55, found from studies of the larvae in the present case, compares closely with the average of 0.52 obtained from studies of pupae in the work referred to by Graham. A recurrence of high populations in 1951 is implied by the absence of any indication of a drop in the sex ratio, such as has been reported to take place toward the end of an outbreak. This implication proved to be correct when the budworm reappeared in outbreak numbers during the 1951 season.

SUMMARY

The use of DDT sprays to control the jack-pine budworm, Choristoneura sp. in jack pine plantations was tested in an experiment conducted in 1950 by the Milwaukee Forest Insect Laboratory in cooperation with the U. S. Forest Service. Heavily infested 10- and 12-year old stands on a half section area within the Rapid River District, Hiawatha National Forest, were sprayed by airplane in June. An oil solution of the insecticide was used, at a dosage rate of 1 pound in 1 gallon of spray per acre.

Two weeks after treatment the reduction in larval population attributable to the insecticide was over 99 percent. One year later the budworm population on the sprayed block was one-fifth of that in the surrounding unsprayed area.

Larval analyses revealed that between 70 and 90 percent of the population was in the fifth and sixth instars at the time of spraying. They also indicated that female development was somewhat slower than male but not sufficiently so to be a limiting factor in control.

Parasitization of the undisturbed larval population was 14.5 percent, while the sex ratio was 0.55; both indicative of a continuance of the outbreak conditions which developed in 1951.

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